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UTILITY PATENT APPLICATION TRANSMITTAL

(For new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No. **P32685**

First Named Inventor or Application Identifier

Storm et al.

"EXPRESS MAIL CERTIFICATE"

"EXPRESS MAIL" MAILING LABEL NUMBER **EL421193832US** DATE OF DEPOSIT: **12 October 2000**

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JC926 U.S. PTO 09/689574 10/12/00

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APPLICATION ELEMENTS *See MPEP chapter 600 concerning utility patent application contents.*	7. ☒ The Title of the Invention: Novel Method of Treatment
1. ☒ The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to Deposit Account No. 19-2570 ☒ General Authorization to charge any and all fees under 37 CFR 1.16 or 1.17, including petitions for extensions of time, relating to this application. (37 CFR 1.136(a)(3)) *(Submit an original, and a duplicate for fee processing)*	8. ☐ Nucleotide and/or Amino Acid Sequence Submission a. ☐ Computer Readable Copy b. ☐ Paper Copy (identical to computer copy) c. ☐ Statement verifying identity of above copies d. ☐ Use the identical computer-readable form filed in Application No. __________, filed ___ _ as the computer-readable form for the instant application. (37 CFR 1.821(e))
2. ☒ The total fee is calculated as shown below: Basic Filing fee $710.00 Total Claims 68 - 20 = 48 x $18 $864.00 Independent Claims 12 -3 = 9 x $80 $720.00 ☐ Multiple Dependent Claim present. $270 TOTAL FILING FEE $2294.00 ☐ Cancel in this application original claims _to __of the prior application before calculating the filing fee. ☒ Charge **$2294.00** to the above indicated Deposit Account.	ACCOMPANYING APPLICATION PARTS 9. a. ☐ Information Disclosure Statement (IDS) b. ☐ PTO-1449 c. ☐ Copies of all IDS Citations 10. ☐ Assignment Papers (cover sheet & document(s)) 11. ☐ Prior Application is Assigned to: ____ *(for continuation/divisional with Box 17a completed*
3. ☒ Specification excluding Drawings [*Total Pages*] 50	12. ☐ Preliminary Amendment [*Total Pages*]
4. ☒ Drawing(s) (35 USC 113) [*Total Sheets*] 7	13. ☒ Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
5. ☒ Declaration and Power of Attorney [*Total Pages*] 3 a. ☐ Newly executed (original or copy) b. ☐ Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional with Box 17a completed)* c. ☒ Unsigned Declaration *[Note Box 6 below]* i. ☐ DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).	14. ☐ Certified Copy of Priority Document(s) *(if foreign priority is claimed)* 15. ☐ Transfer all references cited by Applicants or by the Examiner from the parent Application Serial No.______ filed _______. A PTO-1449 listing the references is enclosed. 16. ☐ Other: ____________

6. ☐ Incorporation By Reference *(useable if Box 5b is checked)*
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 5b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

17. ☒ Priority Information, *check appropriate box and supply the requisite information*

a. The accompanying application is a ☐ Continuation ☐ Divisional ☒ Continuation-in-part (CIP) of prior application No.: 09/544,019 filed 6 April 2000.

b. ☐ Benefit is claimed under Title 35, United States Code, Section 119(e) of the following Provisional Applications: Application No. filed .

c. ☐ Please amend the specification by inserting before the first line the sentence: (37 CFR 1.78) This is a continuation/divisional of application Serial No. ___________ filed __________.

18. CORRESPONDENCE ADDRESS

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19. *RESPECTFULLY SUBMITTED,*

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JC926 U.S. PTO 09/689574 10/12/00

Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

Docket No.: 20.2751
Total Pages = 52

Re: **Application of: Schlumberger Technology Corporation**
For: METHOD AND APPARATUS FOR SUBSURFACE MEASUREMENTS WITH DIRECTIONAL SENSITIVITY PARTICULARLY ADAPTED FOR RESERVOIR MONITORING APPLICATIONS
Full Names of Inventor(s): Dean Homan and Dzevat Omeragic

[X] 37 CFR 1.53(b) UTILITY PATENT APPLICATION TRANSMITTAL, or

[ ] 37 CFR 1.53(b) CONTINUING APPLICATION OF PRIOR APPLICATION NO. ____________________

[ ] Continuation
[ ] Divisional
[ ] Continuation-in-part (CIP)

In accordance with 37 CFR 153(b) enclosed are:

1 [X] Fee Transmittal Form (Original & Duplicate)= 4
2 [X] Patent Application Total No. Pages = 27
3a [ ] Informal Drawings Total No. Pages =
3b [X] Formal Drawings Total No. Pages 14
4 [X] Oath or Declaration Total No. Pages = 3 (includes Power of Attorney)
4a [X] Newly Executed (Original or Copy)
4b [ ] Copy from Prior Application (37 CFR 1.63(d)) for Continuation/Divisional noted above
4c [ ] Deletion of Inventors (Signed Statement Deleting Inventors Named in Prior Application 37 CFR 1.63(d)(2) and 1.33(b)
5 [ ]Incorporation by Reference (Usable if 4b is checked) Entire Disclosure of Prior Application, from which a copy of the oath for declaration is supplied is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein
6 [ ] Amend the specification by inserting before the first line the sentence: This is a [ ] continuation [ ] continuation-in-part [ ] division of application serial no. ________________filed________________.
7 [ ] The prior application is assigned to SCHLUMBERGER TECHNOLOGY CORPORATION.

Accompanying Application Parts

6 [X] Assignment Papers (Cover Sheet & duplicate &document(s))= 4
7 [ ] 37 CFR 3.73(b) Statement
[ ] Power of Attorney
8 [X] Information Disclosure Statement (IDS)PTO-1449
[X] 9 Copies of Citations
9 [ ] Preliminary Amendment
10 [X] Return Receipt Postcard (MPEP 503)
11 [ ] English Translation Document
12 [ ] Certified Copy of Priority Document (if Foreign Priority is Claimed)
13 [ ] Other:

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CLAIMS AS FILED				
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BASIC FEE				$710
TOTAL CLAIMS	74-20=	54	x$18	$972
INDEPENDENT CLAIMS	8-3=	5	x$80	$400
ADDITIONAL FEE FOR FILING ONE OR MORE MULTIPLE DEPENDENT CLAIMS $270				
TOTAL FILING FEE				$2082
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Debra Browning
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Respectfully Submitted,

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Name: Victor H. Segura
Reg. No. 44,329
Date: October 12, 2000

PATENT

20.2751

APPLICATION FOR UNITED STATES LETTERS PATENT

for

Method and Apparatus for Subsurface Measurements with Directional Sensitivity Particularly Adapted for Reservoir Monitoring Applications

by

Dean M. HOMAN and Dzevat OMERAGIC

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NUMBER EL 706 138 908 US

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Debra Browning

METHOD AND APPARATUS FOR SUBSURFACE MEASUREMENTS WITH DIRECTIONAL SENSITIVITY PARTICULARLY ADAPTED FOR RESERVOIR MONITORING APPLICATIONS

1. BACKGROUND OF THE INVENTION

1.1 Field of the Invention

The invention relates to techniques for monitoring and surveying a subsurface reservoir penetrated by a well. More particularly, the invention concerns a method, and a device for its implementation, in which a tubular adapted for permanent disposal is deployed in a borehole. One or more antennas are disposed on the tubular to measure the reservoir properties in a desired direction by selectively steering the sensing direction of electromagnetic energy transmitted and/or received by the antenna(s) and by disposing an antenna on the tubular such that its axis is tilted with respect to the axis of the tubular. The invention has a particularly advantageous application in the collection of information on the displacement of hydrocarbons and water in a subsurface reservoir.

1.2 Description of Related Art

Petroleum is usually produced from oil reservoirs sufficiently far below a gas cap and above an aquifer. As the oil zone is being produced and depleted, the gas cap starts coning downward and the aquifer coning upwards towards the oil bearing zone. Such migration can adversely affect the extraction of petroleum by creating pockets that are missed by the producer and by saturating the oil deposits with water. As soon as either gas or water hits the well, its oil production usually ceases instantly.

Reservoir monitoring includes the process of acquiring reservoir data for purposes of reservoir management. Permanent monitoring techniques are used for long-term reservoir management. In permanent monitoring, sensors are permanently implanted in communication with the reservoir to be managed. For example, in one approach, sensors are permanently situated inside the casing to measure phenomena inside the well such as fluid flow rates or pressure. U.S. Pat. No. 5,467,823 (assigned to the present assignee) describes a technique for monitoring the pressure of the fluid in the reservoir. EP 0964134 A2 describes

a power and signal transmission technique for permanent downhole installations using casing with external reservoir sensors.

Reservoirs are also monitored for changes in saturation and early signatures of coning so that corrective action can be taken. Measuring the electrical resistivity (or its inverse, conductivity) of the formations surrounding a borehole has been used to determine production zones in oil and gas fields and to map sand and shale layers. Electrical resistivity depends directly on porosity, pore-fluid resistivity, and saturation. Porous formations having high resistivity generally indicate the presence of hydrocarbons, while low-resistivity formations are generally water saturated.

U.S. Pat. No. 5,642,051 (assigned to the present assignee) describes a technique incorporating electrodes mounted on the casing exterior to pass a current through the reservoir to measure its electrical resistivity. U.S. Pat. No. 5,992,519 (assigned to the present assignee) describes a technique for active or automated control of a reservoir using a combination of valves and sensors disposed in the wellbore. U.S. Pat. No. 6,023,445 describes a technique for monitoring contact levels of fluids in an oil reservoir. The technique of the '445 patent uses a wireline tool disposed in a monitoring well to take acoustic measurements. U.S. Pat. No. 5,829,520 describes a technique for monitoring a reservoir using an extendable sensor attached to a tubular. U.S. Pat. No. 5,461,594 describes a method for monitoring the displacement of fluids in a reservoir using receivers disposed in a wellbore to detect seismic signals. A primary disadvantage of all these techniques is the inability to steer or focus the measurement of the reservoir property to a specifically desired region.

Thus, there remains a need for an improved method and apparatus for monitoring reservoir properties. It is desirable to implement a technique that provides for long-term selective focusing or steering of reservoir measurements without affecting production.

2. SUMMARY OF THE INVENTION

The invention provides an apparatus for monitoring a characteristic of a reservoir. The apparatus includes a tubular having an elongated body with a longitudinal axis. The tubular is adapted for permanent disposal within a borehole traversing the reservoir. At least

one antenna is disposed on the exterior of the tubular, each antenna having an axis and being adapted for transmission and/or reception of electromagnetic energy. The antenna is disposed on the tubular such that its axis is tilted with respect to the axis of the tubular, and means to activate the antenna to transmit and/or receive electromagnetic energy are provided.

The invention provides another apparatus for monitoring a characteristic of a reservoir. The apparatus includes a tubular having an elongated body with a longitudinal axis. The tubular is adapted for permanent disposal within a borehole traversing the reservoir. An antenna is disposed on the exterior of the tubular, the antenna being adapted to transmit and/or receive electromagnetic energy. Means to activate the at least one antenna to selectively steer the sensing direction of the transmitted and/or received electromagnetic energy are also provided.

The invention provides another apparatus for monitoring a characteristic of a reservoir. The apparatus includes a tubular having an elongated body with a longitudinal axis. The tubular is adapted for permanent disposal within a borehole traversing the reservoir and has at least one slot formed along its elongated body. At least one antenna is disposed on the exterior of the tubular, each antenna having an axis and being adapted for transmission and/or reception of electromagnetic energy. At least one antenna is disposed on the tubular in alignment with a slot, and means to activate at least one antenna to transmit and/or receive electromagnetic energy are provided.

The invention provides another apparatus for monitoring a characteristic of a reservoir. The apparatus includes a tubular having an elongated body with a longitudinal axis. The tubular is adapted for permanent disposal within a borehole traversing the reservoir. At least one saddle coil is disposed on the exterior of the tubular, each saddle coil is adapted for transmission and/or reception of electromagnetic energy, and means to activate the saddle coil to transmit and/or receive electromagnetic energy are provided.

The invention also provides a method for monitoring a reservoir characteristic, the reservoir being traversed by a borehole. The method includes disposing a tubular within the borehole, the tubular having an elongated body with a longitudinal axis. The tubular is adapted for permanent disposal within the borehole and has at least one antenna disposed on its exterior, each antenna having an axis and being adapted for transmission and/or reception

of electromagnetic energy. The method also includes disposing the antenna on the tubular such that its axis is tilted with respect to the axis of the tubular, and activating the antenna to transmit and/or receive electromagnetic energy.

The invention provides another method for monitoring a characteristic of a reservoir, the reservoir being traversed by a borehole. The method includes disposing a tubular within the borehole. The tubular having an elongated body with a longitudinal axis and adapted for permanent disposal within the borehole. The method also includes disposing an antenna on the exterior of the tubular, the antenna being adapted to transmit and/or receive electromagnetic energy; and selectively steering the sensing direction of the transmitted and/or received electromagnetic energy.

The invention provides another method for monitoring a reservoir characteristic, the reservoir being traversed by a borehole. The method includes disposing a tubular within the borehole, the tubular having an elongated body with a longitudinal axis. The tubular is adapted for permanent disposal within the borehole and has at least one slot formed along its elongated body with at least one antenna disposed on the exterior of the tubular in alignment with a slot, each antenna is adapted for transmission and/or reception of electromagnetic energy. The method also includes activating the antenna to transmit and/or receive electromagnetic energy.

The invention provides another method for monitoring a characteristic of a reservoir, the reservoir being traversed by a borehole. The method includes disposing a tubular within the borehole. The tubular has an elongated body with a longitudinal axis and is adapted for permanent disposal within the borehole. The tubular has at least one saddle coil disposed on its exterior; each saddle coil is adapted for transmission and/or reception of electromagnetic energy. The method also includes activating the saddle coil to transmit and/or receive electromagnetic energy.

3. BRIEF DESCRIPTION OF THE DRAWINGS

Other aspects and advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings in which:

Figure 1 is a schematic diagram of a tubular with a recessed station in accord with the invention.

Figure 2 is a schematic diagram of a tubular with an antenna disposed within a recessed station in accord with the invention.

Figure 3 is a schematic diagram of a tubular with two antennas disposed within recessed stations in accord with the invention.

Figure 4 illustrates a set of magnetic moment vectors with a resultant moment that is obtainable with the embodiments of the invention.

Figures 5a-5c illustrate alternative antenna configurations in accord with the invention.

Figure 6 is a schematic diagram of a tubular with an electronics enclosure and an antenna in accord with the invention.

Figures 7a-7c are schematic diagrams of the general volumes of influence to electromagnetic energy obtained with different antenna configurations mounted along a support member.

Figure 8 is a schematic diagram of a tubular with an antenna having a tilted-axis configuration in accord with the invention.

Figure 9 is a schematic diagram of a tubular with an antenna having a tilted axis and a slotted station in accord with the invention.

Figure 10a is a schematic diagram of a tubular with dual tilted antennas in accord with the invention.

Figure 10b is a schematic diagram of a tubular with dual axial antennas and slotted stations in accord with the invention.

Figure 11a is a schematic diagram of a tubular with a shield surrounding the slotted station in accord with the invention.

Figure 11b is a schematic diagram of a tubular with two half-shields surrounding the recessed station in accord with the invention.

Figure 12 is a schematic diagram of a tubular with a tilted antenna configuration in a narrowed and tilted recess in accord with the invention.

Figure 13 is a schematic diagram of a tubular with a bucking antenna and a receiver antenna configuration for use in induction-type measurements in accord with the invention.

Figure 14 is a schematic diagram of a tubular with a tilted antenna configuration for use in propagation-type and/or compensated measurements in accord with the invention.

Figure 15 is a density plot showing a three-dimensional sensitivity distribution in an X-Z plane for a tubular of the invention having transmitter and receiver antennas with axes tilted at 45°.

Figure 16 is a density plot showing a three-dimensional sensitivity distribution in an X-Z plane for a tubular of the invention having a transmitter antenna with a 45°-tilted axis and an axial receiver antenna.

Figure 17 is a density plot showing a three-dimensional sensitivity distribution in an X-Z plane for a tubular of the invention having a transverse (90° tilted) transmitter antenna and an axial receiver antenna.

4. DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Figure 1 shows a tubular 10 embodiment of the invention. A groove is machined about the external circumference of a conventional casing tubular 10, typically made of steel pipe, such that the tubular 10 has a small section with a reduced diameter, thereby forming a recess 12. The recess 12 may be formed in the tubular 10 by machining processes as known in the art or by other suitable means. The depth of the recess 12 may vary depending on the wall thickness of the tubular 10. An exemplary recess 12 may be approximately 1/8-inch deep. The length and diameter of the tubular 10 may also vary as desired. Conventional casing tubulars have an outside diameter ranging from 4.5 to 20 inches and lengths between 16 to 48 feet.

Figure 2 shows an embodiment of the invention. An antenna 14 is disposed within a recess 12 in the tubular 10. In this particular embodiment, the antenna 14 array includes a triad of coils 100, 102, 104 wrapped around the tubular 10. The antenna 14 array is preferably disposed within a recess 12 in the tubular 10, leaving no radial profile to hinder the placement of the tubular 10 within the borehole. The coils of the antenna array are generally of the cylindrical solenoid type and are comprised of one or more turns of insulated

conductor wire that is wound around the tubular 10 as known in the art. The exterior mounting of the antenna 14 array also leaves the inner bore of the tubular unobstructed. Alternatively, the antenna 14 array may be wrapped on a non-recessed segment of the tubular if desired (not shown).

A layer of an electrically insulating material 16, (e.g., Randallite, fiberglass-epoxy, or rubber) is placed between the coils 100, 102, 104 and the body of the tubular 10. The entire recess 12 may be filled with the insulating material so that the antenna 14 array is sealed or potted within the recess 12. In an alternative embodiment, where the tubular is already insulated or formed of a non-conductive material (e.g., fiberglass), the antenna(s) may be directly mounted onto the tubular and sealed with a rubber over-molding (not shown). Nevertheless, it is preferable to maintain a gap or spacing between the coils 100, 102, 104 and the tubular 10.

Figure 3 shows another embodiment of the invention. As known in the art, when the coils 100, 102, 104 are energized with an alternating current to transmit electromagnetic energy (EM), an oscillating magnetic field is produced, resulting in the induction of currents in the surrounding formation which are nearly proportional to its conductivity. These currents, in turn, contribute to the voltage induced at a second antenna 17 array used as a receiver. The receiver antenna 17 array may also be placed within a second recess 12 or at a non-recessed segment of the tubular 10 as desired. While the coils of either antenna are preferably mounted on the tubular 10 such that their axes are mutually orthogonal, the invention may also be implemented with the coils having their axes at varying angles relative to one another.

An aspect of the invention involves electronically "steering" the direction of the magnetic moment resulting from the magnetic field components generated by the transmitter antenna 14 array. A further aspect of the invention involves steering at the receiver antenna 17 array by controlling the relative sensitivities of sensing means that are coupled to the coils 100, 102, 104 forming the receiver antenna 17 array. Before proceeding with disclosure of the invention, some theoretical considerations shall be set forth.

A coil carrying a current can be represented as a magnetic dipole having a magnetic moment proportional to the current. The direction and strength of the magnetic moment can

be represented by a vector perpendicular to the plane of the coil. Corresponding magnetic moment vectors can represent three such coils with non-parallel axes (such as the antennas in Figures 2 and 3). By combining vectors of appropriate magnitudes, one can obtain a resultant magnetic moment vector designated $\overline{M}_T$, in any desired direction and magnitude. Thus, by passing currents of appropriate relative magnitudes through three non-parallel coils, one can obtain a magnetic field that is theoretically equivalent to the magnetic field of a single coil with any desired orientation. Reference is made, for example, to Figure 4, which illustrates magnetic moments designated $\overline{M}_{TX}$, $\overline{M}_{TY}$, and $\overline{M}_{TZ}$, and a resultant magnetic moment $\overline{M}_T$, which is at a (tilt) angle θ with respect to the z axis and which has a projection on the xy plane at an (azimuthal) angle ϕ.

Directionality can also be attributed to the receiver antenna 17 array as follows: If the sensitivities (or amplification factors) of the circuits coupled to individual coils 100, 102, 104 are appropriately selected, the resultant of the signals induced in the three non-parallel coils can be steered to any desired direction. For example, one could consider each of the receiver coils as having a coil moment represented as a vector. The magnitude of the coil moment for each individual coil is proportional to the product of the number of turns times the cross-sectional area of the turns times the adjustable sensitivity (or amplification) attributable to the coil. A receiver coil moment vector, $\overline{M}_R$ can be considered as being made up of the sum of three coil moment components designated $\overline{M}_{RX}$, $\overline{M}_{RY}$, and $\overline{M}_{RZ}$, which correspond to the contributions from three coils having axes in the x, y, and z directions. Additional description of the directionality obtained with the coil arrays of the invention may be found in U.S. Pat. No. 4,360,777 (assigned to the present assignee), incorporated herein by reference.

Figures 5a-5c are diagrammatic views of alternate antenna embodiments of the invention employing a transverse coil configuration using one or more saddle coils. Referring to Figure 5a, a first antenna embodiment is illustrated having segmented coils 101 and 103. These segmented coils together produce a magnetic dipole 200 that extends radially from the tubular (not shown) in which the segmented coils are mounted. As is generally illustrated, the segmented coils 101, 103 are formed to extend about the circumference of a cylindrical portion of the tubular and to receive current out of phase with respect to each

other. Alternatively, the segmented coils 101, 103 may be independently disposed on a tubular and energized to produce the desired magnetic dipole.

Turning to Figure 5b, another antenna embodiment of the invention includes a second set of half-coils 201, 203 that orient and receive current so as to produce a magnetic dipole 300 that also extends radially from the tubular in which the half-coils are mounted. Half-coils 101 and 103 are overlaid to surround half-coils 201 and 203. The half-coils 201, 203 are disposed on the tubular to produce the magnetic dipole 300 so that dipole 300 is rotated azimuthally with respect to the magnetic dipole 200. Figure 5c further illustrates the orientation of these magnetic dipoles 200, 300. These magnetic dipoles 200 and 300, disposed within the borehole 400, are controllable so that the measurement sensitivity may be directed axially from the tubular at any azimuth angle.

The steerable antenna 14, 17 arrays are electronically controlled so that the direction of the resultant radiation pattern maximum may be controlled. The tubulars 10 of the invention include a fluid-tight enclosure 18, which contains electronic circuitry, this circuitry being shown in block form at the side of the tubular 10 in Figure 6. The circuitry enclosure 18 may be affixed to the exterior of the tubular by suitable means as known on the art, including spot welding, fastener means, and straps (not shown). Alternatively, the enclosure 18 may be positioned within the tubular or within a recessed 12 station if desired (not shown). The electronics for activating and steering the antennas of the invention may be configured as described in U.S. Pat. No. 4,360,777.

The antenna 14, 17 arrays are coupled to one end of the circuitry enclosure 18 by a cable 20. The cable 20 is potted within the recess 12 by the insulating material as described above. A wireline 22 is attached at the opposite end of the enclosure 18 for extension to the surface or another location. The wireline 22 may be run externally along a groove milled in the tubular (not shown). In accordance with one embodiment, the wireline 22 may provide AC or DC power to the antennas 14, 17 arrays as well as allow the transmission of data signals from the antennas to the surface and vice-versa. The wireline 22 may also be tethered to the tubular 10 approximately every 30 feet using straps (not shown) or other suitable means as known in the art.

Conventional wells are routinely equipped with tubulars having valves and other apparatus to control flow and production. Such tubulars are equipped with batteries or other means to power these valves and apparatus. It will be appreciated by those skilled in the art that the tubulars 10 of the invention may also be equipped with these known means to power and operate the antenna 14, 17 arrays.

Alternatively, the antenna 14, 17 arrays may be powered by a run-in-tool or buoy (not shown) that is sent from the surface through the tubular 10 as known in the art. The run-in-tool or buoy may be disposed within the tubular 10 for an extended period with power fed to it through a connected wireline or by batteries housed within the tool or buoy. Signal data transfer between the antenna 14, 17 arrays and the tool or buoy may be achieved through matching inductive couplers (not shown) disposed on the tool or buoy and the tubular 10 as known in the art. It will be appreciated by those skilled in the art that other means of power and/or signal transfer between the antenna 14, 17 arrays and the surface may be implemented with the invention.

As described above, an energized transmitter antenna will irradiate the surrounding formation with EM energy. The EM energy is sensed by one or more receiver antennas on the tubular 10. Figure 7a shows the general pattern of antenna 106 sensitivity to EM energy for a typical antenna configuration having non-tilted axes. Figure 7b shows the general pattern of antenna 106 sensitivity for a configuration where the axis of one antenna 106 is tilted relative to the longitudinal tubular 10 axis (represented by the solid line). Figure 7c shows the general pattern of antenna 106 sensitivity for a configuration where the axes of both antennas 106 are tilted relative to the tubular axis. Increased directionality may be achieved when one or both antennas 106 are tilted, as represented by the shaded region of overlap in Figure 7c. Figures 7a-7c show that by tilting the axis of the antenna 106, the axis of its magnetic dipole is rotated, thereby altering the antenna's 106 pattern of influence to EM energy.

Figure 8 shows another embodiment of the invention. In this particular embodiment, an antenna 106 is disposed on the tubular 10 within the recess 12. The antenna 106 is tilted such that its axis, or magnetic moment, is at an angle with respect to the longitudinal axis 24 of the tubular 10. The antenna 106 is insulated from the tubular 10 and the entire recess 12

may be potted with a suitable material as described above. By transmitting EM energy from the tilted antenna 106, a nearby receiver antenna 108 may be used to measure the formation resistivity or other properties at a specific direction in the formation. The direction of maximum azimuthal sensitivity is indicated by the shaded region of overlap in Figure 8.

Figure 9 shows another embodiment of the invention. In this particular embodiment, one or more slots 26 are machined into the tubular 10 to fully penetrate the wall at the recessed 12 station. An antenna 106 is disposed on the tubular 10 in alignment with the slot 26. The slot 26 is formed at an angle with respect to the longitudinal axis of the tubular 10 so that the slot 26 is preferably perpendicular to the antenna 106 at the intersection of the slot 26 and antenna 106. However, if the antenna 106 is mounted co-axially with the tubular 10, the slots 26 are preferably formed parallel to the longitudinal axis of the tubular 10 as shown in Figure 10b. The slot 26 aids in attenuating any current flow around the metallic tubular 10 that may be generated by the current flow in the antenna 106. The length and displacement of the slot(s) 26 may vary. A preferable slot 26 length is three times the extent of the wire thickness of the coil forming the antenna 106.

Hydraulic isolation between the interior and exterior of the tubular 10 is achieved by sealing the slot(s) 26 with Randallite, fiberglass-epoxy, rubber, or any suitable nonconductive material or compound. It will be appreciated that various other means may be used to seal the slot 26, including inserts, internal/external sleeves, and plugs (not shown).

Turning to Figures 10a and 10b, two other embodiments of the invention are shown. Embodiment 10a includes two tilted antennas 106 disposed on the tubular 10. Each antenna 106 is positioned in alignment with a series of slots 26 formed in the tubular 10. Figure 10a also shows the circuitry enclosure 18 and wireline 22 positioned on the tubular 10 as described above.

Figure 10b shows an embodiment of the invention having two antennas 106 mounted on the tubular 10 such that their axes are coaxial with the tubular 10. This configuration will provide for traditional measurement sensitivity. The antennas 106 are also shown positioned in alignment with a series of slots 26 formed in the tubular 10. The slots 26 may be sealed with a nonconductive material or compound as described above.

Figure 11a shows another embodiment of the invention. This particular embodiment is similar to the embodiment of Figure 10b, except that a shield 30 is placed around the recessed station. The shield 30 protects the antenna 106 from damage that may occur while the tubular 10 is placed in the reservoir. The shield 30 may be formed as a cylindrical tube or sleeve to enclose and surround the antenna 106. Protective metal upset rings 34 may be mounted on the tubular 10 above and below the shield 30 to protect the shield 30 on the trip into the well, retaining the shield 30 in position over the slotted 26 station. The upset rings 34 may be mounted on the tubular 10 in a number of ways as known in the art, e.g., spot welding or by fastener means.

The shield 30 is made of an insulating material to permit the passage of EM radiation. Useable materials include the class of polyetherketones described in U.S. Pat. No. 4,320,224, or other suitable resins. *Victrex USA, Inc.* of West Chester, PA manufactures one type called PEEK. *Cytec Fiberite*, *Greene Tweed*, and *BASF* market other suitable thermoplastic resin materials. Another usable insulating material is Tetragonal Phase Zirconia ceramic ("TZP"), manufactured by *Coors Ceramics* of Golden, Colorado. Since the tubular 10 is typically cemented into the borehole traversing the reservoir, the cement job will reinforce the integrity of the shield 30 over the recessed 12 station.

The shield 30 may also be formed of metal. Figure 11b shows a metallic shield 30 embodiment that may be implemented with the invention. In this case, the metallic shield 30 will have one or more slots cut through its walls to permit the passage of EM energy. As shown in Figure 11b, two half-shields 31, 33 are mounted on shoulders 35 of the recess and secured by fastening screws 37, providing a low radial profile. A layer of rubber is provided on the underside of the shield 30 and also fills the slot(s) of the shield (not shown). U.S. Pats. Nos. 4,949,045 and 4,536,714 (both assigned to the present assignee) describe a metallic shield configuration that may be used to implement the invention. Other shield embodiments may be used to implement the invention. For example, a shield 30 may be configured in the form of a strip (not shown), also referred to as flex circuit, to provide flexibility and easy mounting. It will be appreciated that every embodiment of the invention may be configured to include a shield if desired.

Figure 12 shows another embodiment of the invention. In this particular embodiment, an antenna 106 is disposed within a narrow tilted recess 12 formed in the tubular 10. Multiple slots 26 are also provided in the tubular 10 of this embodiment. The slots 26 are sealed and the antenna 106 may be potted within the recess 12 as described above. By narrowing the recess 12, greater structural integrity of the tubular 10 is maintained. The recess 12 may be sealed with Randallite, fiberglass-epoxy, rubber, or any suitable compound permitting the passage of EM energy.

As known in the art, the tubulars 10 of the invention are typically adapted with pin and box threads at the ends for connection to other tubulars (not shown). Given the variable tubular lengths that may be used to implement the invention, a tubular 10 may be equipped with one or more antennas and coupled to a second tubular 10 incorporating one or more antennas itself. With such a configuration, a wireline could be coupled between the tubulars as known in the art, avoiding the need to run multiple wirelines to the surface.

The antennas of the invention may be placed on the tubular 10 in various configurations and energized at various frequencies to measure the properties of a surrounding reservoir. Figure 13 shows another embodiment of the invention. The configuration of this embodiment provides for an induction-type measurement. In addition to a transmitter 106 and receiver antenna 108, the tubular 10 also includes a "bucking" antenna 110 placed near the receiver antenna 108. As known in the art, the signals measured with induction frequencies are affected by direct transmitter-to-receiver coupling. The bucking antenna 110 is used to eliminate or reduce these coupling effects. It will be appreciated by those skilled in the art that the axial spacing and placement of the antennas 106, 108, 110 along the tubular, as well as the transmitting antenna power, may be varied to alter the signal strength and measurement sensitivity. The tubular 10 may be configured and used for induction-type measurements as described in U.S. Pat. No. 5,157,605 (assigned to the present assignee), incorporated herein by reference.

The invention may also be configured and operated to provide propagation-type measurements. As known in the art, propagation-type logging measurements involve the transmission of EM energy into the formation, where energy shed back into the borehole is measured by receivers to determine the relative attenuation and/or the phase shift of the EM

energy propagating in the formation. U.S. Pat. No. 3,551,797 describes a conventional EM propagation logging technique.

Figure 14 shows an embodiment of the invention that may be used for propagation-type measurements. A tubular 10 configured with a transmitter antenna 106 and two receiver antennas 108 is disposed in a horizontal well. The axes of the antennas 106, 108 are tilted with respect to the longitudinal axis of the tubular 10. As described above, this antenna geometry is azimuthally sensitive, allowing for signal measurement in a specific region or direction of interest as depicted by the shaded area in Figure 14. This implementation could be used to monitor the approaching water from a nearby injector well. A resistivity time log would alert the engineer to make appropriate adjustments to the well to safeguard against producing water or other unwanted effects. This configuration allows one to obtain a compensated measurement as known in the art and described in U.S. Pats. Nos. 4,899,112 and 5,594,343 (both assigned to present assignee), incorporated herein by reference.

Turning to Figure 15, a simulated three-dimensional sensitivity distribution is shown for an embodiment of the invention. The density plot of Figure 15 was calculated for a tubular having transmitter and receiver antennas with axes tilted at 45° relative to the longitudinal axis of the tubular (See Fig. 10a). Figure 16 is a simulated three-dimensional sensitivity distribution for another embodiment of the invention. The density plot of Figure 16 was calculated for a tubular having a transmitter antenna with a 45°-tilted axis and an axial receiver antenna (See Fig. 8). Figure 17 is another simulated three-dimensional sensitivity distribution for another embodiment of the invention. The density plot of Figure 17 was calculated for a tubular of the invention having a transverse transmitter antenna and an axial receiver antenna.

While the methods and apparatus of this invention have been described as specific embodiments, it will be apparent to those skilled in the art that variations may be applied to the structures and in the steps or in the sequence of steps of the methods described herein without departing from the concept and scope of the invention. For example, the tubulars of the invention may be configured with multiple transmitter and/or receiver antennas as desired. Cross-well monitoring may also be implemented between boreholes equipped with the tubulars of the invention. Non-metallic tubulars may also be used to implement the

invention. All such similar variations apparent to those skilled in the art are deemed to be within this concept and scope of the invention as defined by the appended claims.

WHAT IS CLAIMED IS:

1. An apparatus for monitoring a characteristic of a reservoir, comprising:
   a tubular having an elongated body with a longitudinal axis, the tubular being adapted for permanent disposal within a borehole traversing the reservoir;
   at least one antenna disposed on the exterior of the tubular, each at least one antenna having an axis and being adapted for transmission and/or reception of electromagnetic energy;
   the at least one antenna being disposed on the tubular such that its axis is tilted with respect to the axis of the tubular; and
   means to activate the at least one antenna to transmit and/or receive electromagnetic energy.

2. The apparatus of claim 1, wherein the reservoir characteristic is resistivity.

3. The apparatus of claim 1, wherein at least two antennas are disposed on the exterior of the tubular such that their axes are tilted with respect to the axis of the tubular.

4. The apparatus of claim 1, the tubular further comprising at least one station having a reduced diameter such that a recess is formed about its external circumference, the at least one antenna being disposed in a recessed station.

5. The apparatus of claim 1, wherein an insulating material is disposed between the tubular body and each at least one antenna disposed thereon.

6. The apparatus of claim 1, further comprising a shield positioned on the exterior of the tubular to surround at least one antenna disposed thereon.

7. The apparatus of claim 6, wherein the shield is formed of a material providing transparency to electromagnetic energy.

8. The apparatus of claim 6, wherein the shield is metallic and has at least one slot formed therein.

9. The apparatus of claim 1, the tubular further comprising at least one slot formed along its elongated body, wherein at least one antenna is disposed on the tubular in alignment with the at least one slot.

10. The apparatus of claim 1, further comprising a wireline coupled to the at least one antenna, the wireline adapted to carry a signal from or to the antenna.

11. An apparatus for monitoring a characteristic of a reservoir, comprising:

a tubular having an elongated body with a longitudinal axis, the tubular being adapted for permanent disposal within a borehole traversing the reservoir;

at least one antenna disposed on the exterior of the tubular, each at least one antenna being adapted to transmit and/or receive electromagnetic energy; and

means to activate the at least one antenna to selectively steer the sensing direction of the transmitted and/or received electromagnetic energy.

12. The apparatus of claim 11, wherein the reservoir characteristic is resistivity.

13. The apparatus of claim 11, wherein the at least one antenna comprises a plurality of coils having non-parallel axes.

14. The apparatus of claim 11, the tubular further comprising at least one station having a reduced diameter such that a recess is formed about its external circumference, the at least one antenna being disposed in a recessed station.

15. The apparatus of claim 11, wherein an insulating material is disposed between the tubular body and the at least one antenna disposed thereon.

16. The apparatus of claim 11, further comprising a shield positioned on the exterior of the tubular to surround the at least one antenna disposed thereon.

17. The apparatus of claim 16, wherein the shield is formed of a material providing transparency to electromagnetic energy.

18. The apparatus of claim 16, wherein the shield is metallic and has at least one slot formed therein.

19. The apparatus of claim 11, the tubular further comprising at least one slot formed along the elongated body, wherein the at least one antenna is disposed on the tubular in alignment with the at least one slot.

20. The apparatus of claim 11, further comprising a wireline coupled to the at least one antenna, the wireline adapted to carry a signal from or to the antenna.

21. An apparatus for monitoring a characteristic of a reservoir, comprising:
a tubular having an elongated body with a longitudinal axis, the tubular being adapted for permanent disposal within a borehole traversing the reservoir;
the tubular having at least one slot formed along its elongated body;
at least one antenna disposed on the exterior of the tubular, each at least one antenna being adapted for transmission and/or reception of electromagnetic energy;
wherein the at least one antenna is disposed on the tubular in alignment with the at least one slot; and
means to activate the at least one antenna to transmit and/or receive electromagnetic energy.

22. The apparatus of claim 21, wherein the reservoir characteristic is resistivity.

23. The apparatus of claim 21, the tubular further comprising at least one station having a reduced diameter such that a recess is formed about its external circumference, the at least one antenna being disposed in a recessed station.

24. The apparatus of claim 21, wherein an insulating material is disposed between the tubular body and each at least one antenna disposed thereon.

25. The apparatus of claim 21, further comprising a shield positioned on the exterior of the tubular to surround at least one antenna disposed thereon.

26. The apparatus of claim 25, wherein the shield is formed of a material providing transparency to electromagnetic energy.

27. The apparatus of claim 25, wherein the shield is metallic and has at least one slot formed therein.

28. The apparatus of claim 21, wherein at least two antennas are disposed on the tubular such that each antenna is in alignment with a slot formed on the tubular.

29. The apparatus of claim 21, further comprising a wireline coupled to the at least one antenna, the wireline adapted to carry a signal from or to the antenna.

30. An apparatus for monitoring a characteristic of a reservoir, comprising:

a tubular having an elongated body with a longitudinal axis, the tubular being adapted for permanent disposal within a borehole traversing the reservoir;

at least one saddle coil disposed on the exterior of the tubular, each at least one saddle coil being adapted for transmission and/or reception of electromagnetic energy; and

means to activate the at least one saddle coil to transmit and/or receive electromagnetic energy.

31. The apparatus of claim 30, wherein the reservoir characteristic is resistivity.

32. The apparatus of claim 30, the tubular further comprising at least one station having a reduced diameter such that a recess is formed about its external circumference, the at least one saddle coil being disposed in a recessed station.

33. The apparatus of claim 30, further comprising a shield positioned on the exterior of the tubular to surround at least one saddle coil disposed thereon.

34. The apparatus of claim 33, wherein the shield is formed of a material providing transparency to electromagnetic energy.

35. The apparatus of claim 33, wherein the shield is metallic and has at least one slot formed therein.

36. The apparatus of claim 30, wherein the tubular comprises a plurality of overlaid coils mounted on the exterior of the tubular.

37. The apparatus of claim 30, further comprising a wireline coupled to the at least one saddle coil, the wireline adapted to carry a signal from or to the coil.

38. A method for monitoring a reservoir characteristic, the reservoir being traversed by a borehole, comprising:

disposing a tubular within the borehole, the tubular having an elongated body with a longitudinal axis, the tubular being adapted for permanent disposal within the borehole and having at least one antenna disposed on the exterior of the tubular, each at least one antenna having an axis and being adapted for transmission and/or reception of electromagnetic energy;

disposing the at least one antenna on the tubular such that its axis is tilted with respect to the axis of the tubular; and

activating the at least one antenna to transmit and/or receive electromagnetic energy.

39. The method of claim 38, wherein the reservoir characteristic is resistivity.

40. The method of claim 38, comprising disposing at least two antennas on the exterior of the tubular such that their axes are tilted with respect to the axis of the tubular.

41. The method of claim 38, the tubular further comprising at least one station having a reduced diameter such that a recess is formed about its external circumference, the at least one antenna being disposed in a recessed station.

42. The method of claim 38, wherein an insulating material is disposed between the tubular body and each at least one antenna disposed thereon.

43. The method of claim 38, further comprising mounting a shield to the exterior of the tubular, the shield positioned to surround at least one antenna disposed thereon.

44. The method of claim 43, wherein the shield is formed of a material providing transparency to electromagnetic energy.

45. The method of claim 43, wherein the shield is metallic and has at least one slot formed therein.

46. The method of claim 38, the tubular further comprising at least one slot formed along the elongated body, wherein the at least one antenna is disposed on the tubular in alignment with the at least one slot.

47. The method of claim 38, further comprising mounting a wireline on the outer surface of the tubular and connecting the at least one antenna to the wireline.

48. A method for monitoring a characteristic of a reservoir, the reservoir being traversed by a borehole, comprising:

disposing a tubular within the borehole, the tubular having an elongated body with a longitudinal axis and adapted for permanent disposal within the borehole;

disposing at least one antenna on the exterior of the tubular, each at least one antenna being adapted to transmit and/or receive electromagnetic energy; and

selectively steering the sensing direction of the transmitted and/or received electromagnetic energy.

49. The method of claim 48, wherein the reservoir characteristic is resistivity.

50. The method of claim 48, wherein the at least one antenna comprises a plurality of coils having non-parallel axes.

51. The method of claim 48, the tubular further comprising at least one station having a reduced diameter such that a recess is formed about its external circumference, the at least one antenna being disposed in a recessed station.

52. The method of claim 48, wherein an insulating material is disposed between the tubular body and the at least one antenna disposed thereon.

53. The method of claim 48, further comprising mounting a shield to the exterior of the tubular, the shield being positioned around the at least one antenna.

54. The method of claim 53, wherein the shield is formed of a material providing transparency to electromagnetic energy.

55. The method of claim 53, wherein the shield is metallic and has at least one slot formed therein.

56. The method of claim 48, the tubular further comprising at least one slot formed along the elongated body, wherein the at least one antenna is disposed on the tubular in alignment with the at least one slot.

57. The method of claim 48, further comprising mounting a wireline on the outer surface of the tubular and connecting the at least one antenna to the wireline.

58. A method for monitoring a reservoir characteristic, the reservoir being traversed by a borehole, comprising:

disposing a tubular within the borehole, the tubular having an elongated body with a longitudinal axis, the tubular being adapted for permanent disposal within the borehole and having at least one slot formed along its elongated body with at least one antenna disposed on the exterior of the tubular in alignment with the at least one slot, each at least one antenna being adapted for transmission and/or reception of electromagnetic energy; and

activating the at least one antenna to transmit and/or receive electromagnetic energy.

59. The method of claim 58, wherein the reservoir characteristic is resistivity.

60. The method of claim 58, wherein the tubular further comprises at least one station having a reduced diameter such that a recess is formed about its external circumference, the at least one antenna being disposed in a recessed station.

61. The method of claim 58, wherein an insulating material is disposed between the tubular body and each at least one antenna disposed thereon.

62. The method of claim 58, further comprising positioning a shield on the exterior of the tubular to surround at least one antenna disposed thereon.

63. The method of claim 62, wherein the shield is formed of a material providing transparency to electromagnetic energy.

64. The method of claim 62, wherein the shield is metallic and has at least one slot formed therein.

65. The method of claim 58, wherein at least two antennas are disposed on the exterior of the tubular such that each antenna is in alignment with at least one slot formed on the tubular.

66. The method of claim 58, further comprising coupling a wireline to the at least one antenna, the wireline adapted to carry a signal from or to the antenna.

67. A method for monitoring a characteristic of a reservoir, the reservoir being traversed by a borehole, comprising:

disposing a tubular within the borehole, the tubular having an elongated body with a longitudinal axis, the tubular being adapted for permanent disposal within the borehole and having at least one saddle coil disposed on its exterior, each at least one saddle coil being adapted for transmission and/or reception of electromagnetic energy; and

activating the at least one saddle coil to transmit and/or receive electromagnetic energy.

68. The method of claim 67, wherein the reservoir characteristic is resistivity.

69. The method of claim 67, wherein the tubular further comprises at least one station having a reduced diameter such that a recess is formed about its external circumference, the at least one saddle coil being disposed in a recessed station.

70. The method of claim 67, further comprising positioning a shield on the exterior of the tubular to surround at least one saddle coil disposed thereon.

71. The method of claim 70, wherein the shield is formed of a material providing transparency to electromagnetic energy.

72. The method of claim 70, wherein the shield is metallic and has at least one slot formed therein.

73. The method of claim 67, further comprising overlaying a plurality of coils on the exterior of the tubular.

74. The method of claim 67, further comprising coupling a wireline to the at least one saddle coil, the wireline adapted to carry a signal from or to the coil.

ABSTRACT

Methods and apparatus for monitoring the properties of a subsurface reservoir are provided. A tubular is equipped with external transmitting and/or receiving antennas configured to provide electromagnetic measurements with directed sensitivity. The tubular includes a recess formed on the outer circumference to house an antenna and electronic components, thereby reducing the tubular radial profile. A shield apparatus is mounted to the tubular to further protect the antennas mounted thereon. A tubular equipped with one or more antennas comprising a coil array, a set of saddle coils, tilted coils, or a combination thereof, provides for selective steering of the measurement sensitivity. Slots are formed on the tubular to attenuate current flow in the tubular that may result from interaction with an antenna mounted thereon. Power and/or signal data transfer between the antennas and the surface is achieved via a wireline coupled between the antennas on the tubular and the surface, or by other suitable means.

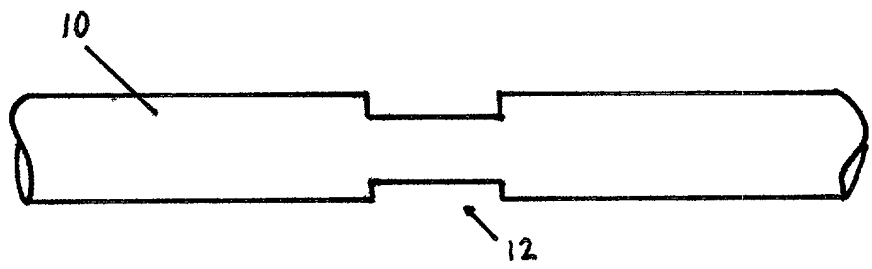


FIG. 1

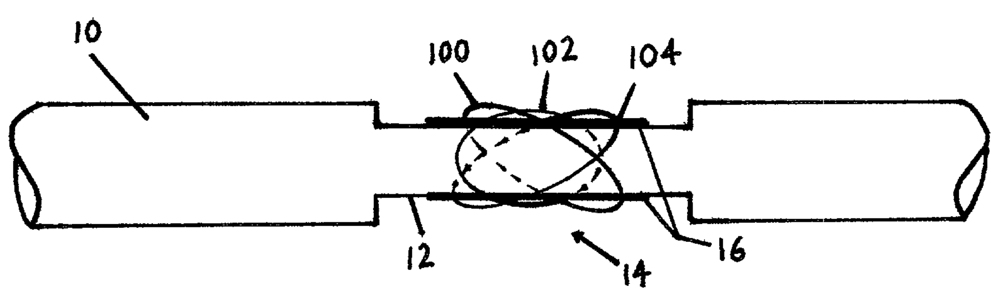


FIG. 2

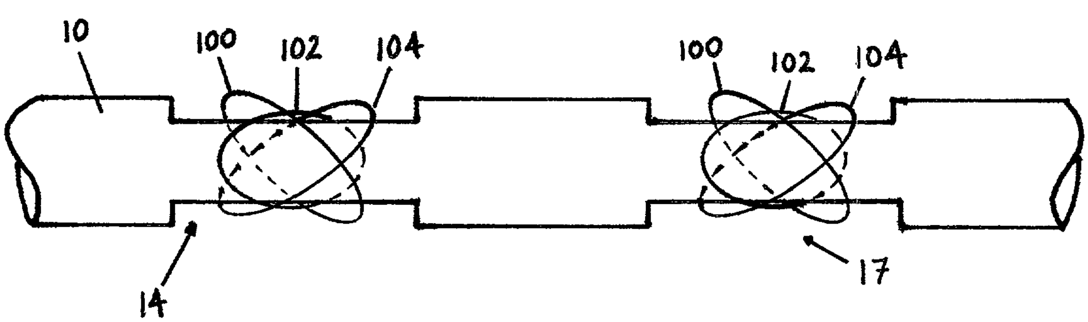


FIG. 3

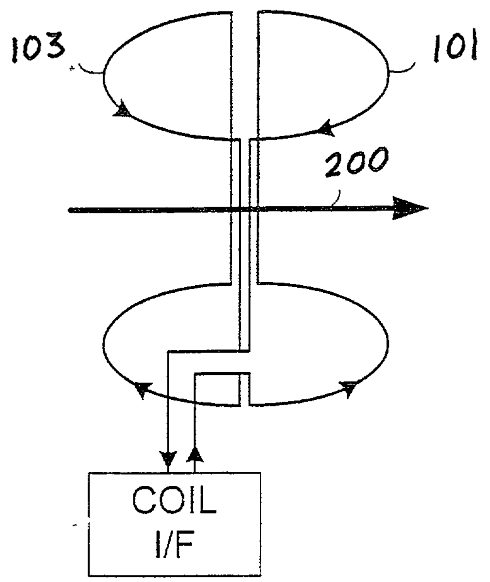


FIG. 5a

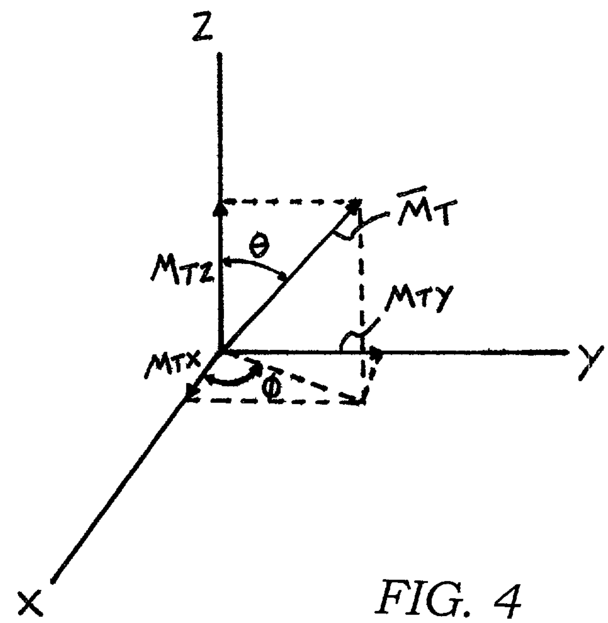


FIG. 4

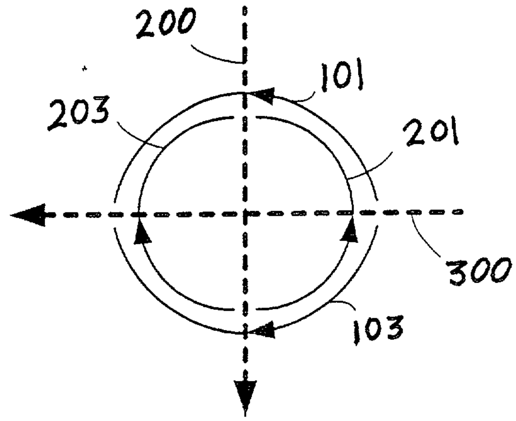


FIG. 5b

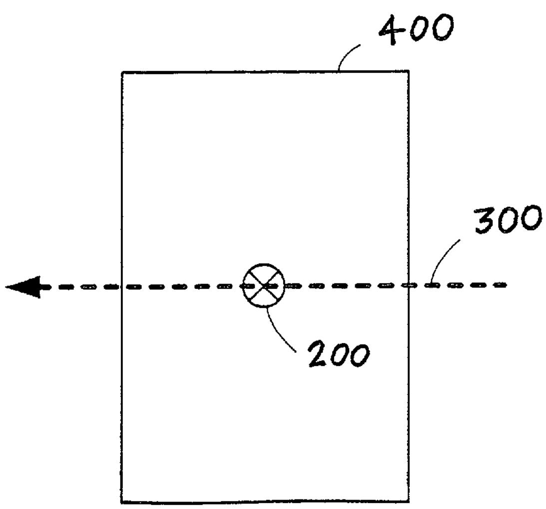


FIG. 5c

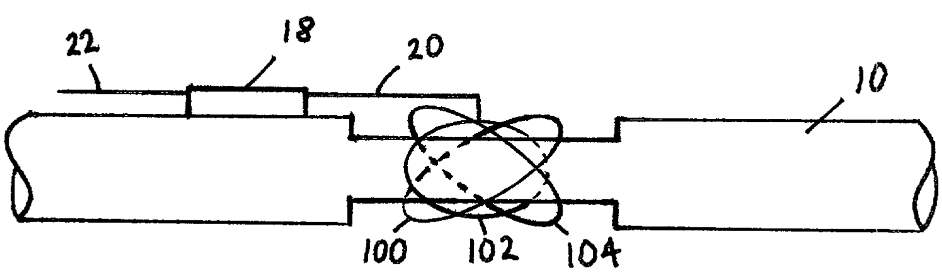


FIG. 6

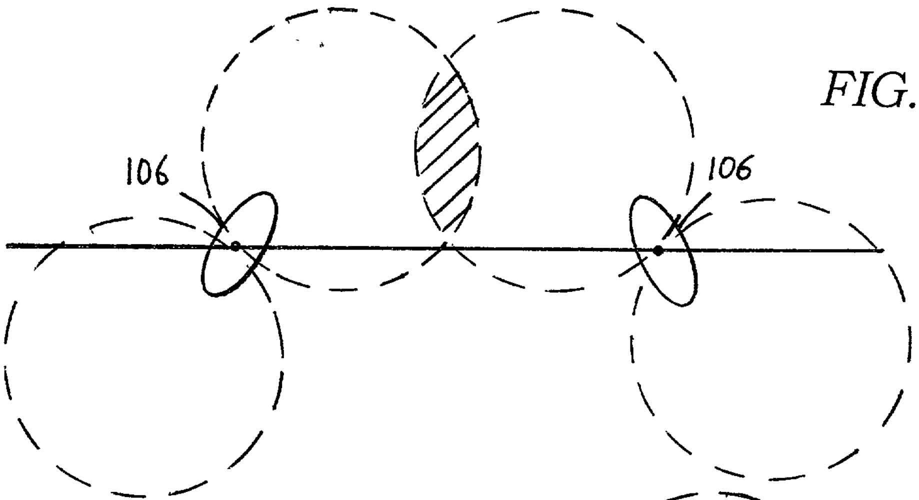


FIG. 7c

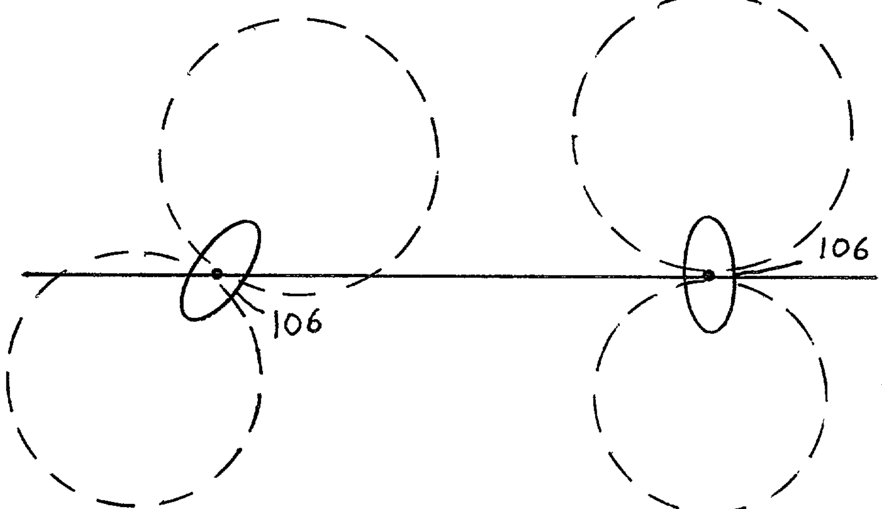


FIG. 7b

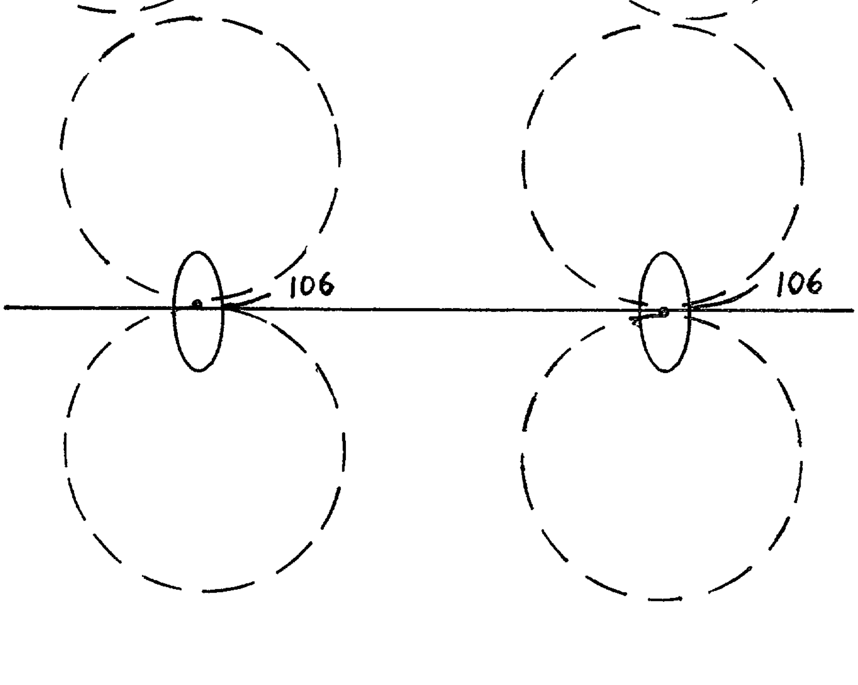


FIG. 7a

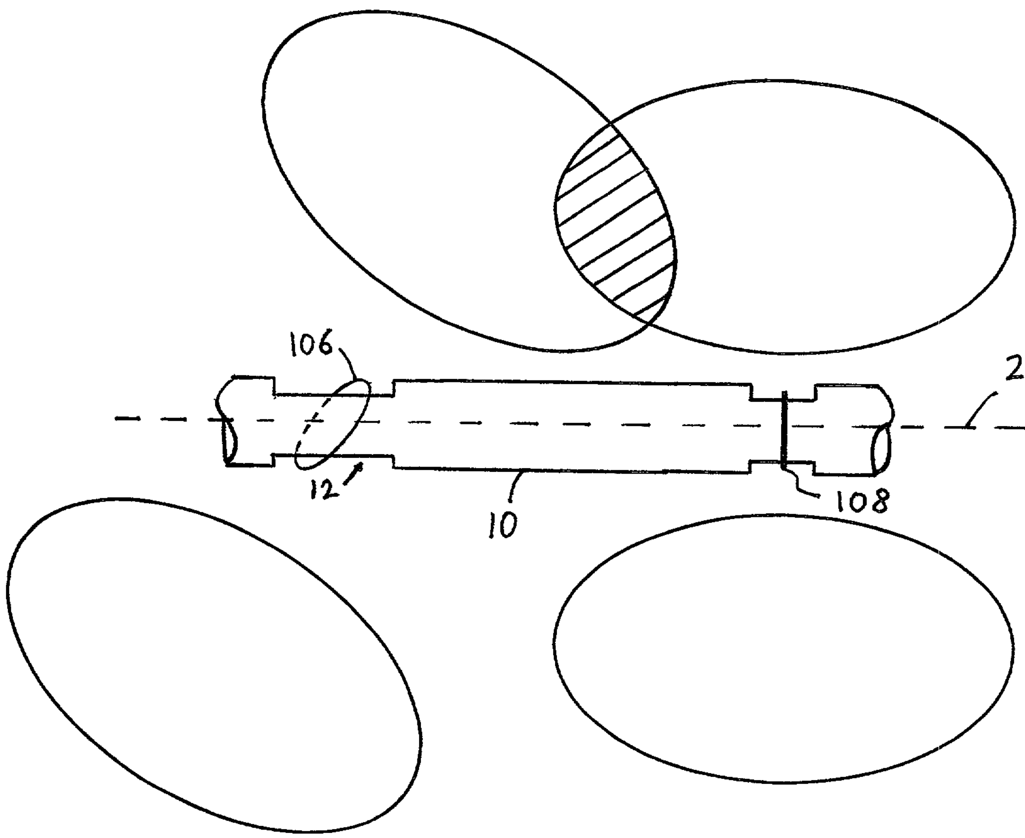


FIG. 8

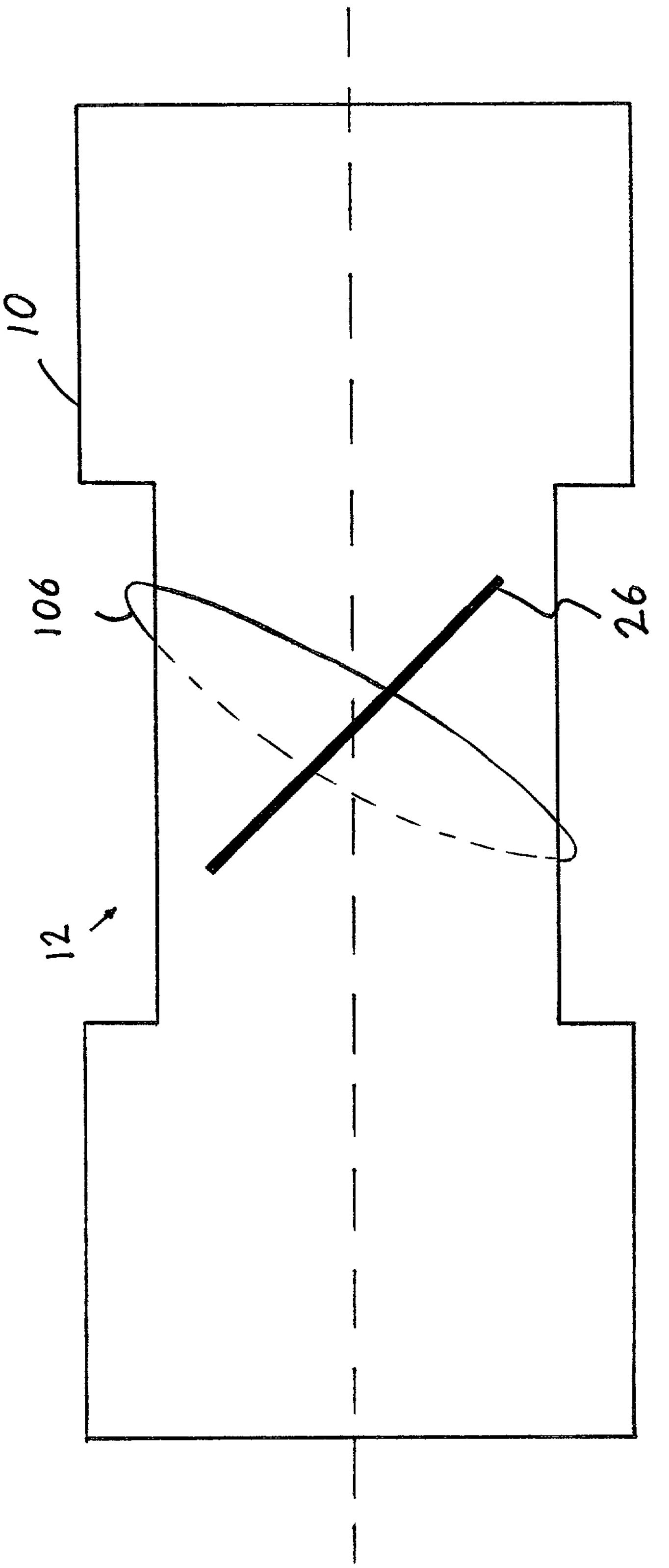


FIG. 9

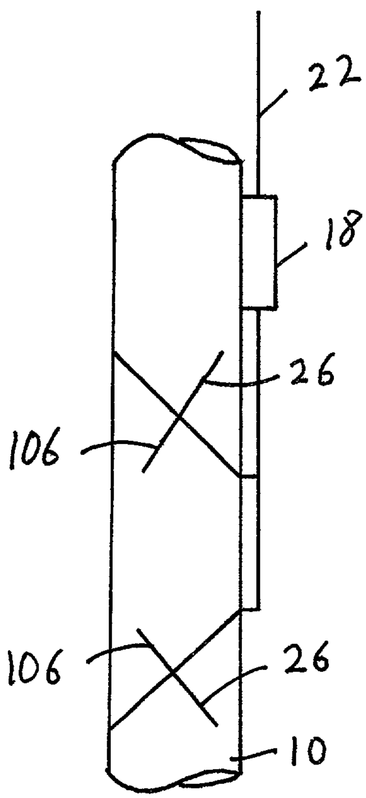


FIG. 10a

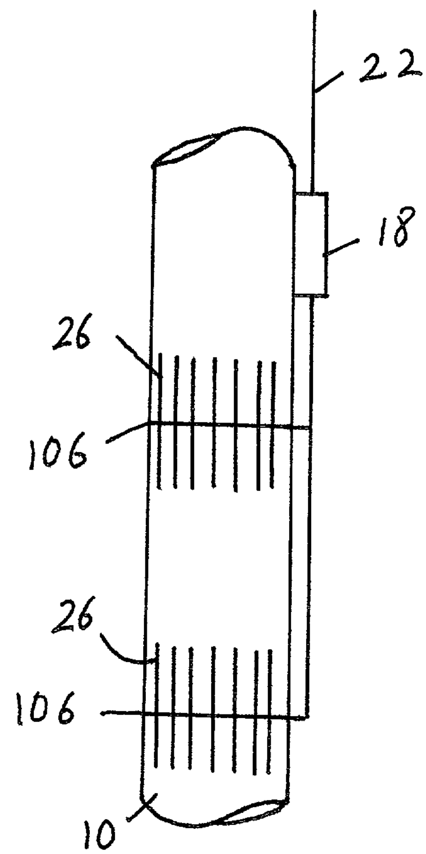


FIG. 10b

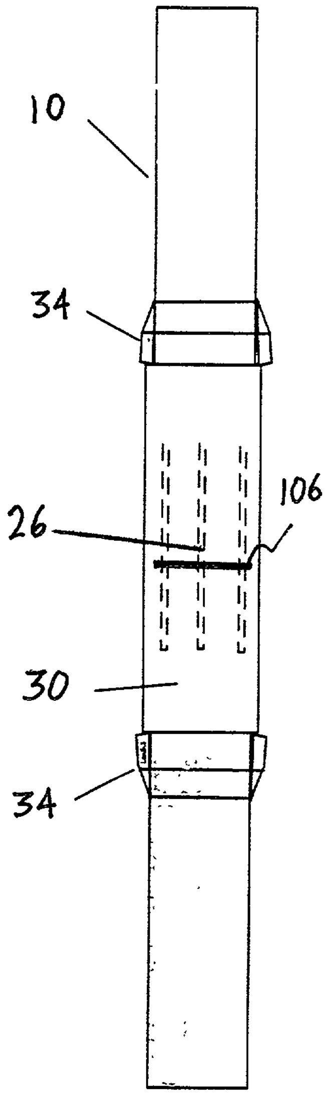


FIG. 11a

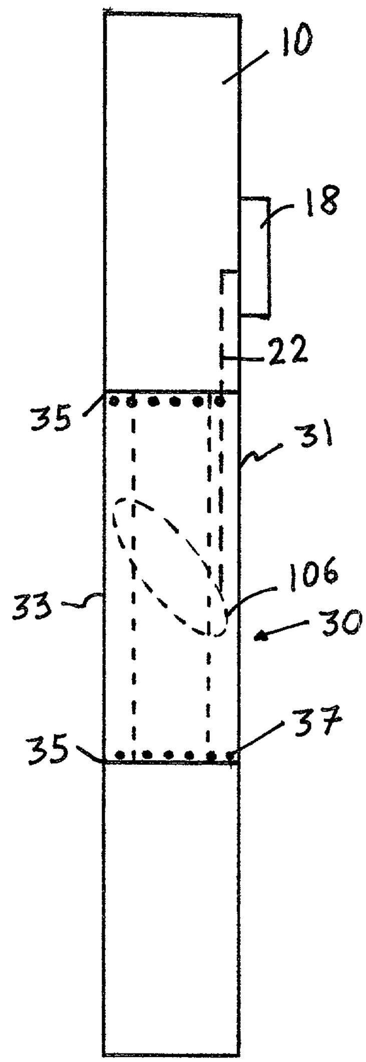


FIG. 11b

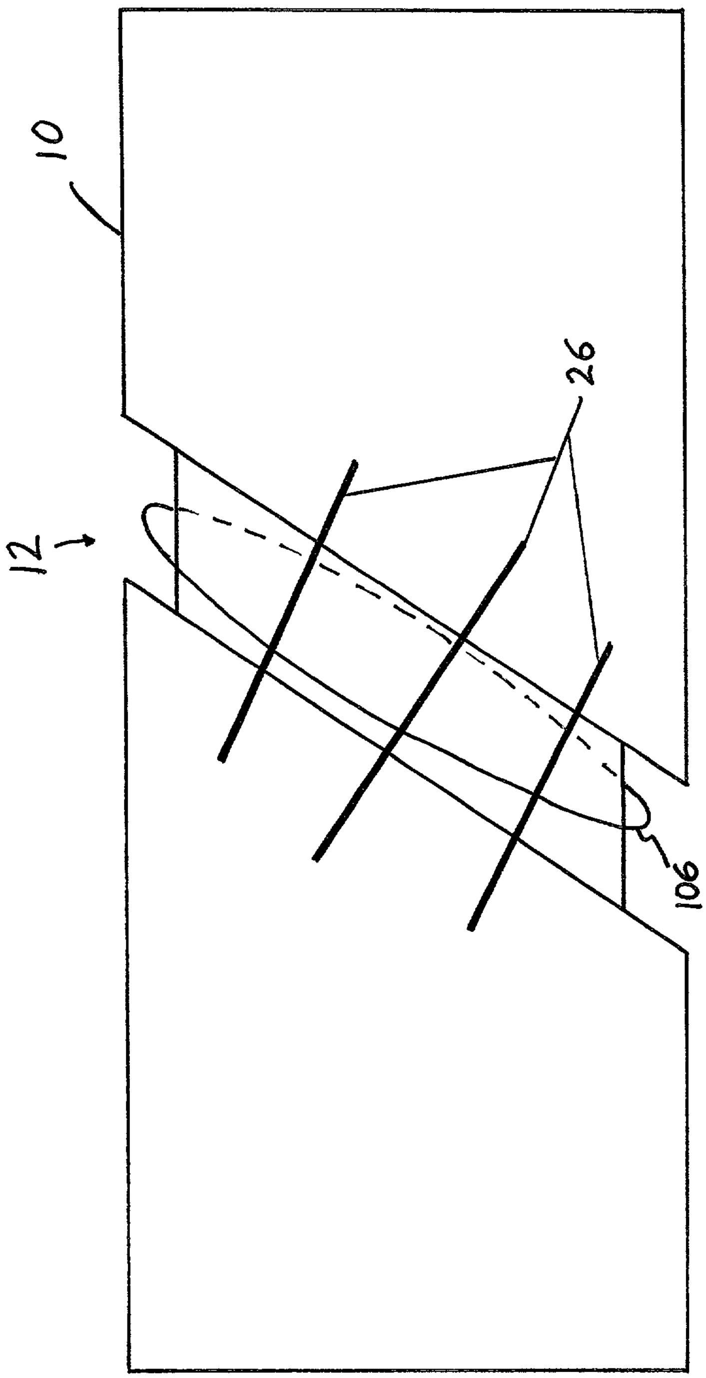


FIG. 12

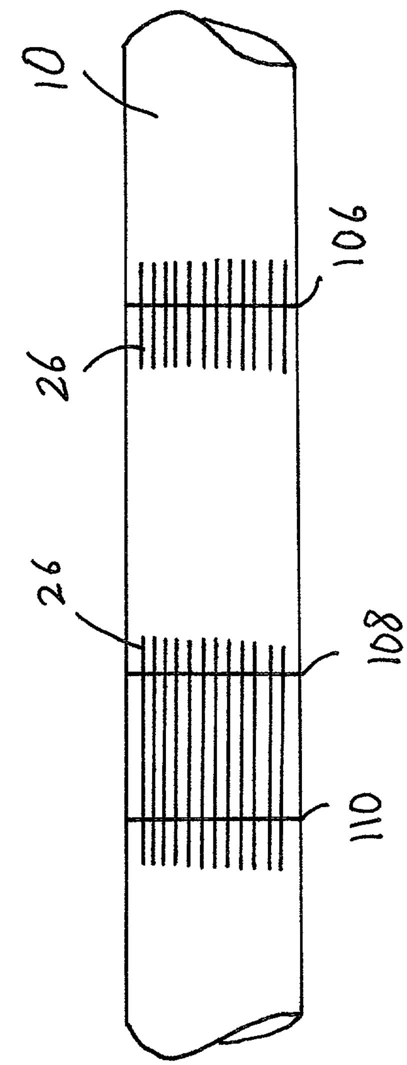


FIG. 13

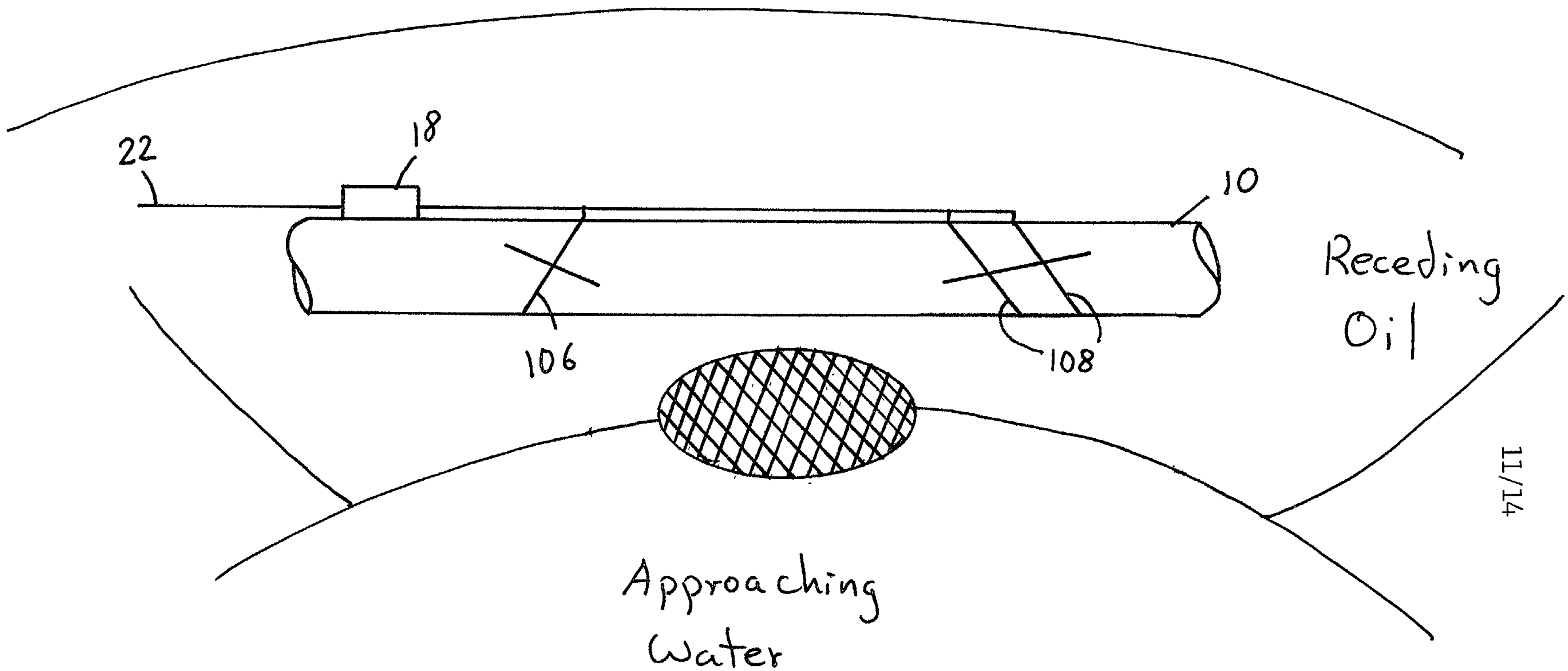
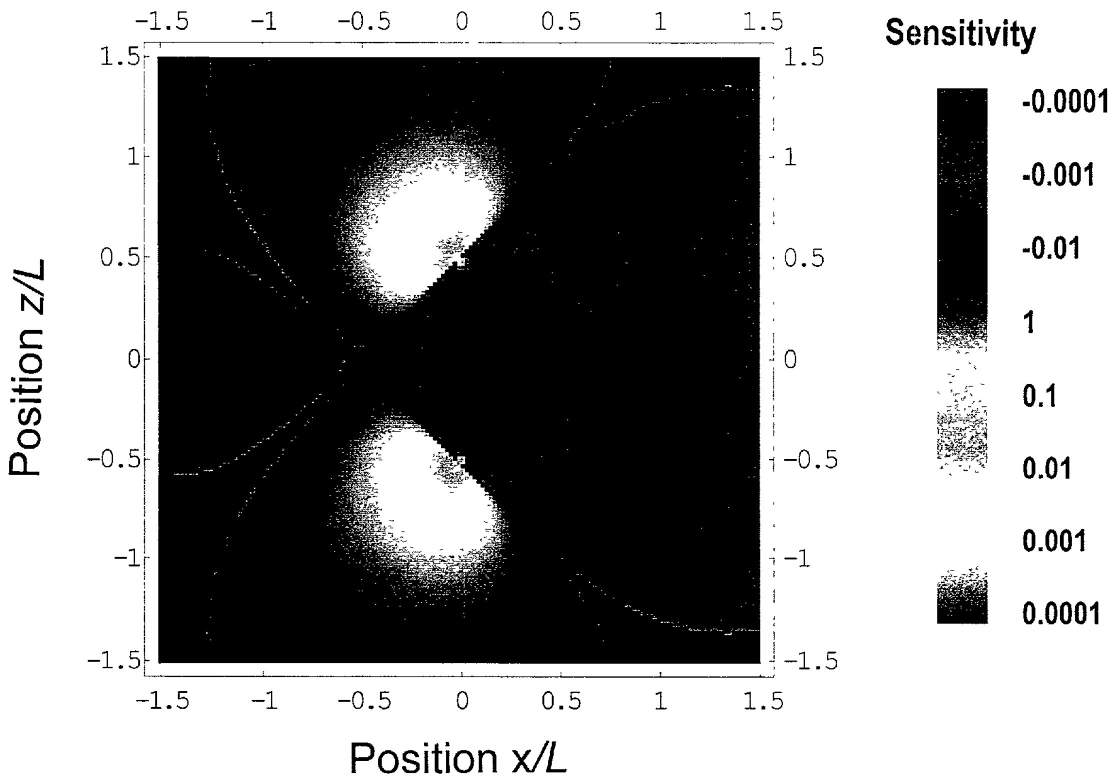


FIG. 14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-0.01
1
0.1
0.01
0.001
0.0001
Position z/L
Position x/L
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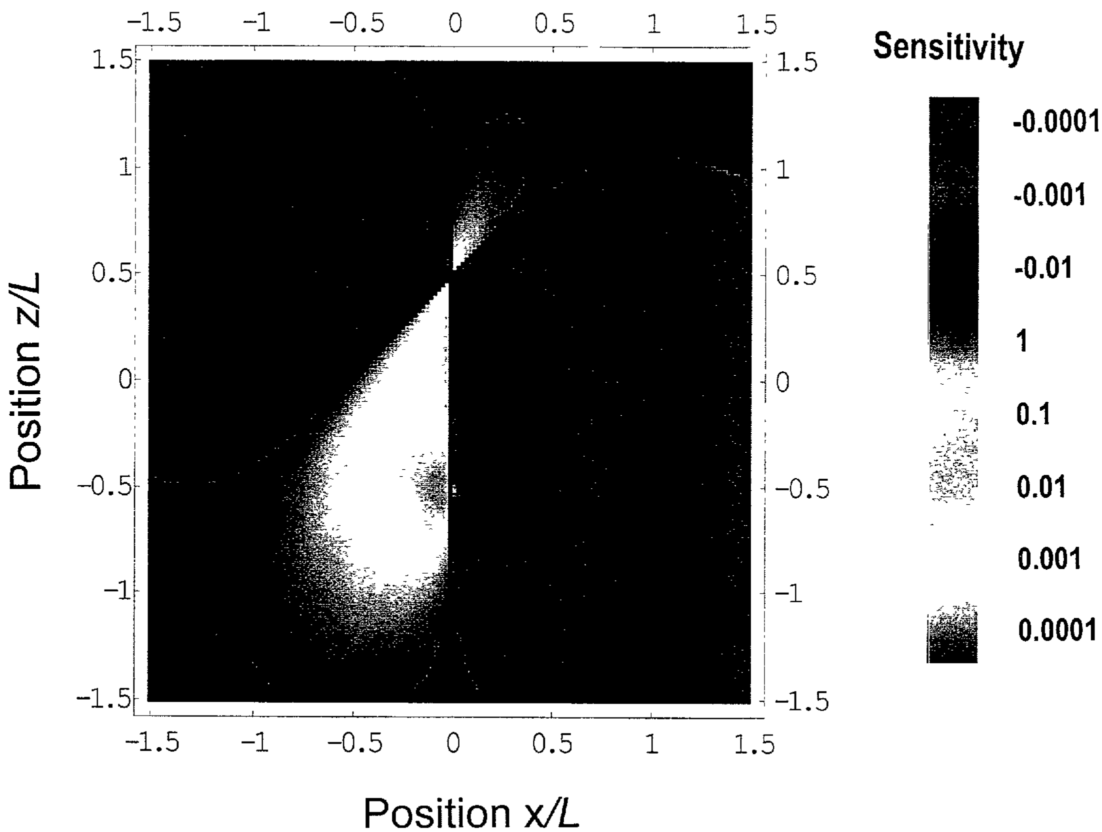
-1
-0.5
0
0.5
1
1.5

FIG. 15


Sensitivity
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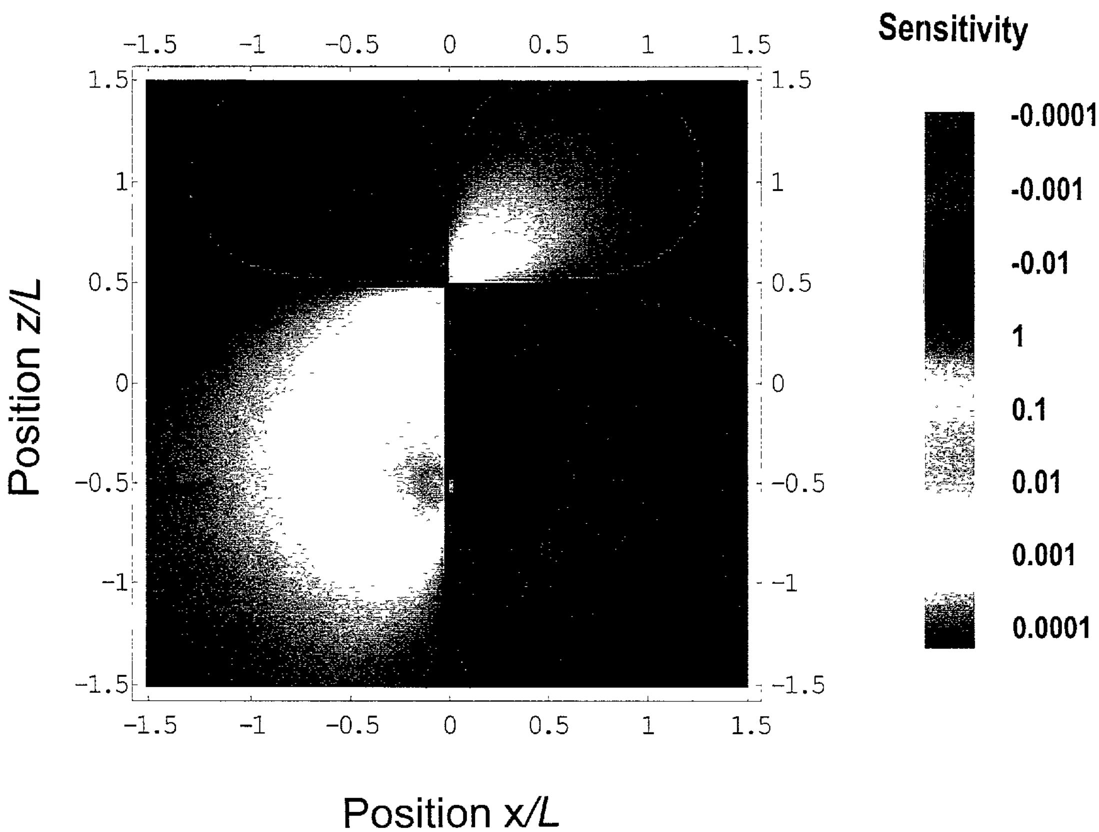
1.5

FIG. 16


Sensitivity
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-0.01
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0.01
0.001
0.0001
-1.5
-1
-0.5
0
0.5
1
1.5
Position z/L
Position x/L

FIG. 17

20.2751

DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name, and

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD AND APPARATUS FOR SUBSURFACE MEASUREMENTS WITH DIRECTIONAL SENSITIVITY PARTICULARLY ADAPTED FOR RESERVOIR MONITORING APPLICATIONS

the specification of which

[x] is attached hereto.

[ ] was filed on ____________________

as Application Serial Number ______________________

or PCT International Application Number ____________

and was amended on (if applicable) ________________

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119 of any foreign application(s) for patent or inventor's certificate , or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below any foreign application for patent or inventor's certificate or of any PCT international application having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)		Priority Claimed
________________ (Number) (Country)	/ / / D/M/YR FILED	[ ] YES [ ] NO
________________ (Number) (Country)	/ / / D/M/YR FILED	[ ] YES [ ] NO
________________ (Number) (Country)	/ / / D/M/YR FILED	[ ] YES [ ] NO

20.2751

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below:

______________________	______________________
Application No.	Filing Date
______________________	______________________
Application No.	Filing Date

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

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Application Serial No.	Filing Date	Status-patented, pending, abandoned
____________	________	____________________
Application Serial No.	Filing Date	Status-patented, pending, abandoned

As a named inventor, I hereby appoint the following attorney(s) and/or agents(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

John J. Ryberg, #31,134; Brigitte L. Jeffery, #38,925; Steven L. Christian, #38,106 and Victor H. Segura, #44,329. I hereby request that all correspondence, notices, official letters and other communication be directed to Schlumberger Technology Corporation, ATTN: IP Counsel, P. O. BOX 2175, Houston, Texas 77252-2175; and that all telephone calls be directed to: Victor H. Segura, at (281) 285 4562, Schlumberger Oilfield Services, P. O. BOX 2175, Houston, Texas 77252-2175. Schlumberger U.S. PTO Customer No. is 23718.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

20.2751

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